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On the Value of the Parallactic Inequality. By James Campbell, Esq., and E. Neison, Esq.

The Note by Mr. Stone in the *Monthly Notices* for June seems to call for a brief explanation from us, which we beg now to lay before the Society.

We consider that our last communication to the Society (*Monthly Notices*, March 1881) contains a satisfactory proof of the validity of the correction for the effects of the irradiation at the lunar limb which has been employed by us in our investigation. Mr. Stone would still seem to be of opinion that such proof is wanting, and merely repeats two objections shown by us in our last communication to be due to a misunderstanding and therefore to be quite untenable, as if he had overlooked this portion. We need add nothing further, therefore, on this point.

With regard to the third section of Mr. Stone's Note, the only point which seems to call for any reply is the objection he has urged that we have employed an erroneous value of the semi-diameter of the Moon in the reduction of the observations for the period 1851–1858. It appears to us that Mr. Stone's objection can be summed up as follows: These observations have been reduced by us with Adams' semi-diameter plus the correction ($-0''.18$), whereas we ought to have used, as before, Hansen's value plus the correction ($+0''.24$),* and consequently our results ought to be increased by $+0.94$, or the difference between the *mean* values of the semi-diameter according to Hansen and Adams when similarly corrected.

We dissent entirely from this conclusion.

In determining the value of the parallactic inequality it is

* By some inadvertence Mr. Stone calls it $+0''.29$.

essential that the observations should be reduced with the observed value of the lunar semi-diameter, and if the observed value be employed it is quite immaterial what the tabular value may be. In all our results we have employed the observed value, and if no mention has been made of a correction for converting the tabular value (Adams') into the observed value, it is solely because for this particular period the observed and tabular semi-diameters coincided in value. When, however, we come to compare Adams' value for the semi-diameter founded on Adams' corrected version of Burckhardt's tabular parallax with Hansen's value for the semi-diameter founded on his own tables, it is found that a small correction ($-0''.18$) * must be employed. It follows, therefore, that our results rest directly on the observed semi-diameters, and do not, as Mr. Stone supposes, require a correction for the difference between the *mean* semi-diameters of Adams and Hansen.

Mr. Stone seems to think that the same mean correction to the semi-diameter should be employed at all epochs. From this we dissent, for as the observers change, even if it be merely in the relative frequency of their observations, as they become more experienced, and as the imperfections in the tables develop themselves, so will vary the correction necessary to reduce the tabular to the observed semi-diameter.

The difficulties imagined by Mr. Stone in the last paragraph of his paper do not seem weighty: the constant difference of $+1''.60$ between the results prior and subsequent to the change of instruments in 1816 is exactly what might be anticipated by the change of aperture, and its reality is clearly shown by the observations themselves. It is exactly analogous to the corresponding change which occurred in 1851, when a similar change of instruments occurred.

Mr. Stone also lays special stress on the fact that the results for the years 1846–1851 (for an examination of the results for the separate years will show that it is only these years which are discordant) do not agree with those made at earlier periods. This admitted discordance we were disposed to attribute to some change of observers at this epoch. Further examination confirms this; for it shows that towards the end of 1845 such a change did occur. For many years previous to this date the regular observers had been Mr. Henry and Mr. Thomas Ellis, but at this date Mr. Rogerson replaced Mr. Ellis. In 1846 Mr. Dunkin replaced Mr. Rogerson, but towards the middle of the year Mr. Dunkin again gave place to Mr. Rogerson. Towards the end of 1848, the practice of all four assistants taking regular part in the observations was introduced, and continued until quite lately. No very abundant material exists for comparing the observations of Messrs. Rogerson and Dunkin with those of Mr. Ellis through those of Mr. Henry, but a reduction of the

* The value found from our own comparison was $-0''.15$; that used seems to have been deduced in a similar manner at Greenwich.

only existing data clearly shows that whilst the diameter of the Moon according to Messrs. Rogerson and Dunkin agreed with that according to Mr. Henry, the diameter according to Mr. Ellis was entirely different, he having a very great personality (amounting to nearly $3''{\cdot}00$) in this respect. Therefore, to render the results for the years 1846–1851 comparable with those for the earlier years, the effect of this personality must be considered; and it results that the parallactic inequality for these years must be increased by nearly $2''{\cdot}00$. With this correction the discordance vanishes.

We submit, therefore, that these objections which have been made to the validity of the results obtained by us in our investigations have been shown to be illusory, and though Mr. Stone may not see this just at present, we are confident that, with the evidence already published, this is a view which will be confirmed by those astronomers who are properly versed in these matters.

Note on Mr. Gill's Ascension Observations. By G. F. Hardy, Esq.

In his Paper summarising the results of the observations made at Ascension with a view to determine the solar parallax, Mr. Gill gives an expression for the error in R.A. of the tabular places of *Mars*, which includes a term depending upon twice the mean longitude of the Moon. Mr. Gill seems to consider the existence of this term somewhat doubtful, or at least as unexplained. It will be remembered, however, that the geocentric places of the planets equally with the Sun are affected by the revolution of the Earth round the common centre of gravity of itself and its satellite, the magnitude of the resulting irregularity depending upon the apparent angular diameter of the small orbit thus described, as seen from the planet in question. The *Nautical Almanack* places of *Mars* being from Leverrier's tables, we may suppose that the magnitude of this irregularity was determined on the basis of Leverrier's estimate of $8''{\cdot}95$ for the value of the solar parallax. As this is now known to be too large, it follows that the magnitude of the irregularity alluded to is also over-estimated in the *Nautical Almanack* tables, and that the observed places will be alternately behind and in front of the tabular places of the planet. It is, of course, only owing to the fact that the observations extend through a comparatively short period that the necessary correction can be fairly represented by a term having a constant coefficient, as its value does not actually depend upon the Moon's longitude alone, but on the difference of the longitude of the Moon and planet, and further, on the ratio of their respective parallaxes. Assuming that the term given by Mr. Gill represents with sufficient nearness the correction required, and that we may assume a constant average parallax for the planet during the period through which the

observations extended, it is easy to calculate approximately the correction required by Leverrier's value of the parallax. Assuming the average tabular parallax of *Mars* during the Ascension observations to have been 21″, and taking Mr. Gill's constant ″·376 as the correction to be deducted from this value, we have for the correction to the Sun's tabular parallax of 8″·95,

$$-\frac{''\cdot 376 \times 8\cdot 95}{21\cdot 00} = -''\cdot 16.$$

Thus, we get 8″·95 − ″·16 = 8″·79, agreeing extremely well with the general result of Mr. Gill's observations.

I have for some time thought that an extension of the method employed by Leverrier in the case of the Sun to determine the parallax of some of the nearer planets, would probably be attended with success, and the result brought out incidentally by Mr. Gill seems to support this view. One of the main difficulties would be the accurate determination of the Moon's mass. Probably, sufficiently numerous and exact observations exist to determine the lunar parallax to within $\frac{1}{100000}$th of its actual value, *i.e.* to about ″·03, while the length of the seconds pendulum may be considered as already known with an equal exactitude; these two data should therefore give us the value of the Moon's mass to within the $\frac{1}{1000}$th part of the truth. As respects other methods of determining the solar parallax, it appears to me that something more might probably be accomplished by a careful analysis of existing observations of *Jupiter's* satellites, treating the diameters of the planet and of the satellites as unknown quantities to be determined from the eclipse observations, and taking into account the possible effect of the refraction of the Jovian atmosphere (which may be considerable) on the times of disappearance and reappearance.

Stroud Green, N.,
1881, *July* 13.

On the Determination of the Moon's Libration.

By A. Marth, Esq.

In the method which has been adopted in several investigations of the Moon's libration, the apparent position of a spot referred to the centre of the Moon's disk and to the circle of declination is deduced from the measured distances and position-angles of a number of points of the Moon's limb in reference to the spot; from the apparent coordinates thus found the selenocentric right ascension and declination of the spot are deduced, and these are converted into ecliptical longitude and latitude. Comparison is then made with the selenocentric longitude and

latitude computed from approximate values of the spot's selenographical coordinates and of the inclination of the lunar equator to the ecliptic, and the equations are found which exhibit the effect of corrections of these values and of the terms due to physical libration.

It appears preferable to follow another course; to proceed from assumed selenographical coordinates of the spot to its apparent coordinates referred to the centre of the Moon's disk and the direction of the Moon's axis, to determine the corrections of these coordinates which best satisfy the measurements, and to form the equations between the corrections and the effect of the Moon's physical libration, &c., upon these coordinates.

Let I denote the assumed inclination of the plane of the lunar equator to the ecliptic; $\Omega + 180°$ the longitude of its ascending node, which coincides with the descending node of the orbit; J its inclination to the plane of the Earth's equator; N the right ascension of the ascending node. If, further, l_0 is the mean longitude of the Moon in its orbit and $M + 180°$ the arc of the lunar equator between equator and ecliptic, let $l_0 - \ + M + N$ be denoted by α_0. The departure of the first or zero meridian, from which the selenographical longitudes are reckoned, from the ascending node $\Omega + 180°$ of the lunar equator on the ecliptic, is, in consequence of the equality of the periods of rotation and mean revolution, $= l_0 - \Omega$, and therefore its departure from the ascending node of the lunar equator on the Earth's equator

$$= l_0 - \Omega + M + 180° = \alpha_0 - N + 180°,$$

so that the angle α_0 is in reference to the equator analogous to l_0 in reference to the ecliptic.

Ephemerides of the position of the lunar equator referred to that of the Earth have been given in the *Berliner Jahrbuch* since 1839, and in the *Nautical Almanac* since 1867, the notation and formulæ adopted being those employed by Encke in his paper "Ueber die selenocentrischen Constanten bei den Sternbedeckungen und die Berechnung der Libration des Mondes, nebst Tafeln," in the *Berliner Jahrbuch* for 1843. Instead of the arc of the lunar equator between the Earth's equator and the ecliptic, therein given, it will be found far more convenient to have the value of α_0, which is in Encke's notation

$$= l_0 - \Omega + 180° + \Delta + \Omega'.$$

For the present purpose the Ephemerides will have to be computed rather more accurately, l_0 and Ω being duly referred to the true equinox. Since, moreover, other formulæ will be found preferable to Encke's, there would be no advantage in retaining his designations i, Δ and Ω', which are replaced by the letters J, $M + 180°$ and N in the present paper.

The values of α_0, N and J may be deduced from those of l_0,

Ω, I, and of the apparent obliquity ε of the ecliptic by means of the formulæ

$$\begin{aligned}
\tan \eta &= -\tan \mathrm{I} \cos \Omega, \\
\tan \mathrm{N} &= -\tan \mathrm{I} \sin \Omega \cdot \frac{\cos \eta}{\sin (\epsilon + \eta)}, \\
\tan \mathrm{J} &= \tan (\epsilon + \eta) \sec \mathrm{N}, \\
\sin \tfrac{1}{2} (\alpha_0 - l_0) &= -\frac{\sin \tfrac{1}{2} \mathrm{I} \sin \tfrac{1}{2} \epsilon}{\cos \tfrac{1}{2} \mathrm{J}} \cdot \sin \Omega.
\end{aligned}$$

The next proceeding is the computation of the position-angle P of the Moon's axis, and of the selenographical longitude Λ and latitude B of the centre of the Moon's disk as seen by the observer. Let α' and δ' be the apparent right ascension and declination of the Moon's centre, which are derived from the geocentric right ascension and declination α and δ, if θ is the sidereal time, by

$$\begin{aligned}
r' \cos \delta' \sin (\alpha' - \alpha) &= -\rho' \sin (\theta - \alpha), \\
r' \cos \delta' \cos (\alpha' - \alpha) &= r \cos \delta - \rho' \cos (\theta - \alpha), \\
r' \sin \delta' &= r \sin \delta - \rho'',
\end{aligned}$$

or by equivalent formulæ, in which $r \left(= \frac{\mathrm{I}}{\sin \pi}\right)$ and r' are the linear distances of the Moon's centre from the Earth's centre and from the observer, and ρ' and ρ'' the perpendicular distances of the observer from the Earth's axis and from the plane of the equator, the unit of these distances being the equatoreal semidiameter of the Earth. The selenocentric spherical triangle between the pole of the lunar equator, the pole of the celestial equator and the observer furnishes the equations:

$$\begin{aligned}
\cos \mathrm{B} \sin \mathrm{P} &= -\sin \mathrm{J} \cos (\alpha' - \mathrm{N}), \\
\cos \mathrm{B} \cos \mathrm{P} &= +\sin \mathrm{J} \sin (\alpha' - \mathrm{N}) \sin \delta' + \cos \mathrm{J} \cos \delta', \\
\sin \mathrm{B} &= +\sin \mathrm{J} \sin (\alpha' - \mathrm{N}) \cos \delta' - \cos \mathrm{J} \sin \delta', \\
\cos \mathrm{B} \sin (\Lambda + \alpha_0 - \mathrm{N}) &= \cos \mathrm{J} \sin (\alpha' - \mathrm{N}) \cos \delta' + \sin \mathrm{J} \sin \delta', \\
\cos \mathrm{B} \cos (\Lambda + \alpha_0 - \mathrm{N}) &= \cos (\alpha' - \mathrm{N}) \cos \delta';
\end{aligned}$$

from which latter two may be deduced

$$\begin{aligned}
\cos \mathrm{B} \sin (\Lambda + \alpha_0 - \alpha') &= [\sin \delta' - \tan \tfrac{1}{2} \mathrm{J} \sin (\alpha' - \mathrm{N}) \cos \delta'] \sin \mathrm{J} \cos (\alpha' - \mathrm{N}) \\
&= (\sin \delta' - \sin \mathrm{B}) \tan \tfrac{1}{2} \mathrm{J} \cos (\alpha' - \mathrm{N}).
\end{aligned}$$

Hence are derived the formulæ for the computation of P, B and Λ:—

$$\begin{aligned}
\tan \zeta &= \tan \mathrm{J} \sin (\alpha' - \mathrm{N}), \\
\tan \mathrm{P} &= -\tan \mathrm{J} \cos (\alpha' - \mathrm{N}) \cdot \frac{\cos \zeta}{\cos (\zeta - \delta')}, \\
\tan \mathrm{B} &= \tan (\zeta - \delta') \cdot \cos \mathrm{P}, \\
\sin (\Lambda + \alpha_0 - \alpha') &= \frac{\sin \mathrm{B} - \sin \delta'}{2 \cos^2 \tfrac{1}{2} \mathrm{J}} \cdot \sin \mathrm{P}, \\
\text{or} &= \frac{\sin \tfrac{1}{2} (\mathrm{B} - \delta') \cos \tfrac{1}{2} (\mathrm{B} + \delta')}{\cos^2 \tfrac{1}{2} \mathrm{J}} \cdot \sin \mathrm{P}, \\
\text{or} &= \frac{\sin (\zeta' - \delta')}{\cos \zeta'} \cdot \sin \mathrm{P} \quad , \text{if } \tan \zeta' = \tan \tfrac{1}{2} \mathrm{J} \sin (\alpha' - \mathrm{N}).
\end{aligned}$$

Then follows the computation of the apparent position of the spot. If λ and β are the selenographical longitude and latitude of the spot, and p its position-angle at the centre of the disk, as seen by the observer, we have selenocentrically, if the angular distance between spot and observer is called S,

$$\begin{aligned}
\sin S \sin (p-P) &= \cos\beta \sin (\Lambda-\lambda),\\
\sin S \cos (p-P) &= -\cos\beta \cos (\Lambda-\lambda) \sin B + \sin\beta \cos B,\\
\cos S &= \cos\beta \cos (\Lambda-\lambda) \cos B + \sin\beta \sin B.
\end{aligned}$$

If the linear distance of the spot from the Moon's centre of gravity is k' and from the observer r'', the unit of distances being, as before, the semi-diameter of the Earth's equator, the angular distance s of the spot from the centre of the disk, as seen by the observer, and r'' are found by

$$\begin{aligned}
r'' \sin s &= k' \sin S,\\
r'' \cos s &= r' - k' \cos S;
\end{aligned}$$

or, indirectly, by

$$\sin s = \frac{k'}{r'} \sin (S+s),$$

$$r'' = r' \cdot \frac{\sin S}{\sin (S+s)}.$$

The coordinates

$$\begin{aligned}
x'' &= \omega'' \sin s \sin (p-P), \qquad (\omega'' = \frac{1}{\text{arc } 1''} = 206264''{\cdot}8),\\
y'' &= \omega'' \sin s \cos (p-P),
\end{aligned}$$

or the apparent rectangular coordinates of the spot in reference to the centre of the disk and to the computed direction of the Moon's axis seem to me the most suitable for the determination of the libration. The corrections of x'' and y'' which best satisfy the observations, compared with the variations of x'' and y'' which represent the effect of the corrections of the assumed values of I, λ, β, and of the different terms of the physical libration, furnish then the equations of condition for the determination of the latter.

In the differentiation of the equation for x'' and y''

$$x'' = \frac{\omega'' k'}{r''} \cdot \sin S \sin (p-P) = \frac{\omega'' k'}{r''} \cdot \cos\beta \sin (\Lambda-\lambda),$$

$$y'' = \frac{\omega'' k'}{r''} \cdot \sin S \cos (p-P) = \frac{\omega'' k'}{r''} [-\cos\beta \cos (\Lambda-\lambda) \sin B + \sin\beta \cos B],$$

it must be borne in mind that P as a function of the assumed

elements is itself variable, so that if the corrected values $x''+\delta x''$ and $y''+\delta y''$ are to refer to the same direction P as x'' and y'' themselves, the variation of P must be duly taken into account. Differentiating accordingly, we get

$$\begin{aligned}\delta x'' = \frac{k'}{r''}\Big\{ & \cos\beta\cos(\Lambda-\lambda)\,\delta(\Lambda-\lambda)\\ & -\sin\beta\sin(\Lambda-\lambda)\,\delta\beta\\ & +\sin S\cos(p-P)\,\delta P\Big\}\\ & + x''\cdot\frac{\delta k'}{k'},\end{aligned}$$

$$\begin{aligned}\delta y'' = \frac{k'}{r''}\Big\{ & \cos\beta\sin B\sin(\Lambda-\lambda)\,\delta(\Lambda-\lambda)\\ & +[\cos\beta\cos B+\sin\beta\sin B\cos(\Lambda-\lambda)]\,\delta\beta\\ & -[\cos\beta\cos B\cos(\Lambda-\lambda)+\sin\beta\sin B]\,\delta B\\ & -\sin S\sin(p-P)\,\delta P\Big\}\\ & + y''\cdot\frac{\delta k'}{k'}.\end{aligned}$$

From the expressions of Λ, B, P are derived

$$\begin{aligned}\delta\Lambda = & -\delta\alpha_0-[\tan B\sin(\alpha_0-N+\Lambda)-\tan\tfrac{1}{2}J]\sin J.\delta N\\ & -\tan B\cos(\alpha_0-N+\Lambda)\,\delta J,\\ \delta B = & -\cos(\alpha_0-N+\Lambda)\sin J.\delta N+\sin(\alpha_0-N+\Lambda)\,\delta J,\\ \cos B.\delta P = & -\sin(\alpha_0-N+\Lambda)\sin J.\delta N-\cos(\alpha_0-N+\Lambda)\,\delta J.\end{aligned}$$

But, if

$$M=\alpha_0-N-(l_0-\Omega),$$

then

$$\begin{aligned}\delta\alpha_0 = & \quad \delta l_0-(\tan\tfrac{1}{2}J\cos M+\tan\tfrac{1}{2}I)\sin I.\delta\Omega\\ & -\tan\tfrac{1}{2}J\sin M.\delta I,\\ \sin J.\delta N = & -\cos M\sin I.\delta\Omega-\sin M.\delta I,\\ \delta J = & +\sin M\sin I.\delta\Omega-\cos M.\delta I.\end{aligned}$$

Hence

$$\begin{aligned}\delta\Lambda = & -\delta l_0+[\tan B\sin(l_0-\Omega+\Lambda)+\tan\tfrac{1}{2}I]\sin I.\delta\Omega\\ & +\tan B\cos(l_0-\Omega+\Lambda)\,\delta I,\\ \delta B = & \cos(l_0-\Omega+\Lambda)\sin I.\delta\Omega-\sin(l_0-\Omega+\Lambda)\,\delta I,\\ \cos B.\delta P = & \sin(l_0-\Omega+\Lambda)\sin I.\delta\Omega+\cos(l_0-\Omega+\Lambda)\,\delta I,\end{aligned}$$

the substitution of which gives

$$\delta x'' = \frac{k' \cos \beta}{r''} \Big\{ - \cos (\Lambda - \lambda)\,(\delta l_0 + \delta\lambda) - \tan \beta \sin (\Lambda - \lambda)\,\delta\beta + [\tan \beta \sin (l_0 - \Omega + \Lambda) + \tan \tfrac{1}{2} \mathrm{I} \cos (\Lambda - \lambda)] \sin \mathrm{I}.\delta\Omega + \tan \beta \cos (l_0 - \Omega + \Lambda)\,\delta\mathrm{I} \Big\} + x'' \cdot \frac{\delta k'}{k'},$$

$$\delta y'' = \frac{k' \cos \beta}{r''} \cos \mathrm{B} \Big\{ - \tan \mathrm{B} \sin (\Lambda - \lambda)\,(\delta l_0 + \delta\lambda) + [1 + \tan \beta \tan \mathrm{B} \cos (\Lambda - \lambda)]\,\delta\beta - [\cos (l_0 - \Omega + \lambda) + \tan \beta \tan \mathrm{B} \cos (l_0 - \Omega + \Lambda) - \tan \tfrac{1}{2} \mathrm{I} \tan \mathrm{B} \sin (\Lambda - \lambda)] \sin \mathrm{I}.\delta\Omega + [\sin (l_0 - \Omega + \lambda) + \tan \beta \tan \mathrm{B} \sin (l_0 - \Omega + \Lambda)]\,\delta\mathrm{I} \Big\} + y'' \cdot \frac{\delta k'}{k'};$$

or, putting

$$\tan \beta \tan \mathrm{B} \sin (\Lambda - \lambda) = \nu \sin (\lambda_1 - \lambda)$$
$$1 + \tan \beta \tan \mathrm{B} \cos (\Lambda - \lambda) = \nu \cos (\lambda_1 - \lambda),$$

then

$$\delta y'' = \frac{k' \cos \beta}{r''} \cos \mathrm{B} \Big\{ - \tan \mathrm{B} \sin (\Lambda - \lambda)\,(\delta l_0 + \delta\lambda) + \nu \cos (\lambda_1 - \lambda)\,\delta\beta - [\nu \cos (l_0 - \Omega + \lambda_1) - \tan \tfrac{1}{2} \mathrm{I} \tan \mathrm{B} \sin (\Lambda - \lambda)] \sin \mathrm{I}.\delta\Omega + \nu \sin (l_0 - \Omega + \lambda_1)\,\delta\mathrm{I} \Big\} + y'' \cdot \frac{\delta k'}{k'}.$$

The physical libration produces oscillations in the values of l_0, Ω and I, the theoretical investigation of which is to be found in the *Méc. Cél.* L. v., and in the papers of Poisson (*Conn. des Temps*, for 1821 and 1822), Bessel (*Astr. Nachr.* Nos. 376 and 377, or *Abhandlungen*, iii. pp. 317–328), Wichmann (*Astr. Nachr.* Nos. 619, 621, 628, 630, 631), and Hartwig (*Beitrag zur Bestimmung der physischen Libration des Mondes*, 1880). If i denotes the inclination of the Moon's orbit to the ecliptic, e its eccentricity, ω the angle in the orbit from the node to the perigee, g the Moon's mean anomaly and Σ (H sin h) the sum of the several inequalities of the motion in longitude, which produce sensible terms; if, further, m', n', π' denote the daily motions of the mean longitude, of the node and of the perigee, and h' the daily motion of h, all of which quantities are known: the oscillations of l_0, Ω

and I, due to the physical libration, may be represented by the following equations:—

$$\delta l_0 = \sum\left(-\mathrm{H} \cdot \frac{\theta\,(1-f)}{1+f\theta} \cdot \sin h\right) + a_0 \sin(\mathrm{A}_0 + \nu_0 t),$$

$$\begin{aligned}
\sin \mathrm{I}\delta\Omega = {} & \sin \mathrm{I}\,\delta l_0 \\
& -\kappa q \cos\omega \sin(l_0-\Omega) \\
& +\kappa q' f \sin\omega \cos(l_0-\Omega) \\
& +b_0 \sin[\mathrm{B}_0+\mu t-(l_0-\Omega)] \\
& +c_0 \sin(\mathrm{C}_0+\mu' t)\cos(l_0-\Omega) \\
& +\frac{2c_0}{\sqrt{f}} \cos(\mathrm{C}_0+\mu' t)\sin(l_0-\Omega),
\end{aligned}$$

$$\begin{aligned}
\delta \mathrm{I} = {} & -\kappa q \cos\omega \cos(l_0-\Omega) \\
& -\kappa q' f \sin\omega \sin(l_0-\Omega) \\
& -b_0 \cos[\mathrm{B}_0+\mu t-(l_0-\Omega)] \\
& -c_0 \sin(\mathrm{C}_0+\mu' t)\sin(l_0-\Omega) \\
& +\frac{2c_0}{\sqrt{f}} \cos(\mathrm{C}_0+\mu' t)\cos(l_0-\Omega),
\end{aligned}$$

in which f, a_0, A_0, b_0, B_0, c_0, C_0 are the seven constants of the problem which are to be determined, and in which θ, κq, $\kappa q'$, ν_0, μ, μ' have the following values:—

$$\left.\begin{aligned}
\theta' &= \frac{-2n'm'}{h'h'} \cdot \frac{\mathrm{I}}{i+\mathrm{I}} \\
\theta &= \frac{\theta'}{1-\theta'},
\end{aligned}\right\} \text{ for each of the effective inequalities,}$$

$$\kappa q = \frac{-n'e\mathrm{I}}{\pi'-n'} \cdot \left(1 + \frac{0{\cdot}0391\,i}{i+\mathrm{I}}\right),$$

$$\kappa q' = \frac{-2n'e\mathrm{I}}{\pi'-n'},$$

$$\nu_0 = \sqrt{-2n'm'} \cdot \frac{\mathrm{I}}{i+\mathrm{I}} \cdot \sqrt{1-f},$$

$$\mu = m' - \frac{n'\mathrm{I}}{i+\mathrm{I}},$$

$$\mu' = -\frac{4}{3} \cdot \frac{n'\mathrm{I}}{i+\mathrm{I}} \cdot \sqrt{f}.$$

In order to compute the coefficients of the unknown quantities correctly, the values of I and f employed must be sufficiently near the true ones, or the computation will have to be repeated with corrected values. Instead of f itself, it will be preferable to make the correction δf of the best available value of f, the unknown quantity, or rather δf multiplied by a properly chosen factor κ'', so that in the equation for δl_0 the term

$$\sum\left(\frac{\mathrm{H}}{\kappa''} \cdot \frac{\theta\,(1+\theta)}{(1+\theta f)^2} \sin h\right)\kappa''\delta f$$

is to be added to the term

$$\Sigma\left(-\mathrm{H}\,.\,\frac{\theta\,(1-f)}{1+\theta f}\,\sin h\right),$$

which is to be considered as known.

The substitution of the values of δl_0, $\delta\Omega$, and $\delta\mathrm{I}$, which represent the effect of the physical libration, in the previously given equations for $\delta x''$ and $\delta y''$, furnishes then the equations:

$$\delta x'' = -\frac{\kappa k'\cos\beta}{r''}\times$$

$$\left\{\left(\cos(\Lambda-\lambda)-\tan\beta\,\tan\mathrm{I}\sin(l_0-\Omega+\Lambda)\right)\ \Sigma\left(-\frac{\mathrm{H}\cos\mathrm{I}}{\kappa}\,.\,\frac{\theta\,(1-f)}{1+\theta f}\,\sin h\right)\right.$$

$$+\ q\,\tan\tfrac{1}{2}\,\mathrm{I}\sin g\cos(\Lambda-\lambda)$$

$$+\ q\,\tan\beta\cos(\omega+\Lambda)$$

$$\left.+\,(q-q'f)\,\tan\beta\sin\omega\sin\Lambda\right\}$$

$$-\frac{\kappa k'\cos\beta}{r''}\left\{\ +\cos(\Lambda-\lambda)\,.\,\frac{\delta\lambda}{\kappa}\right.$$

$$+\ \tan\beta\sin(\Lambda-\lambda)\,.\,\frac{\delta\beta}{\kappa}$$

$$\left.-\ \tan\beta\cos(l_0-\Omega+\Lambda)\,.\,\frac{\delta\mathrm{I}}{\kappa}\right.$$

$$+\Big[\quad[\cos(\Lambda-\lambda)-\tan\beta\,\tan\mathrm{I}\sin(l_0-\Omega+\Lambda)]\ \ \Sigma\left(\frac{\mathrm{H}\cos\mathrm{I}}{\kappa\kappa''}\,.\,\frac{\theta\,(1+\theta)}{(1+\theta f)^2}\,\sin h\right)$$

$$-\frac{q'}{\kappa''}\tan\beta\sin\omega\sin\Lambda\Big]\kappa''\delta f$$

$$+\left(\cos(\Lambda-\lambda)-\tan\beta\,\tan\mathrm{I}\sin(l_0-\Omega+\Lambda)\right)\,.\,\frac{a_0}{\kappa}\sin(\mathrm{A}_0+\nu_0 t)$$

$$+\ \tan\beta\,.\,\frac{b_0}{\kappa}\cos(\mathrm{B}_0+\mu t+\Lambda)$$

$$-\ \tan\beta\,.\,\frac{2}{\sqrt{f}}\,.\,\frac{\cos\Lambda}{\cos\Lambda_1}\,.\,\frac{c_0}{\kappa}\cos(\mathrm{C}_0+\mu' t-\Lambda_1)\Big\},$$

$$\text{if}\ \tan\Lambda_1=\frac{\sqrt{f}}{2}\tan\Lambda$$

$$+\frac{x''}{100}\,.\,\frac{100\,\delta k'}{k'}\ ;$$

and, putting as before

$$\nu\sin(\lambda_1-\lambda)=\ +\tan\beta\,\tan\mathrm{B}\sin(\Lambda-\lambda),$$
$$\nu\cos(\lambda_1-\lambda)=1+\tan\beta\,\tan\mathrm{B}\cos(\Lambda-\lambda),$$

then

$$\delta y'' = -\frac{\kappa k' \cos\beta}{r''} \cdot \cos B \cdot \nu \times$$

$$\left\{ \left(\tan I \cos (l_0 - \Omega + \Lambda) + \frac{\tan B}{\nu} \sin (\Lambda - \lambda) \right) \Sigma \left(-\frac{H \cos I}{\kappa} \cdot \frac{\theta (1-f)}{1+\theta f} \sin h \right) \right.$$

$$+ q \tan \tfrac{1}{2} I \sin g \cdot \frac{\tan B}{\nu} \sin (\Lambda - \lambda)$$

$$+ q \sin (\omega + \lambda_1)$$

$$\left. + (q - q' f) \sin \omega \cos \lambda_1 \right\}$$

$$-\frac{\kappa k' \cos\beta}{r''} \cdot \cos B \cdot \nu \left\{ + \frac{\tan B}{\nu} \sin (\Lambda - \lambda) \frac{\delta\lambda}{\kappa} \right.$$

$$+ \cos (\lambda_1 - \lambda) \frac{\delta B}{\kappa}$$

$$\left. - \sin (l_0 - \Omega + \lambda_1) \cdot \frac{\delta I}{\kappa} \right.$$

$$+ \left[\left(\tan I \cos (l_0 - \Omega + \Lambda) + \frac{\tan B}{\nu} \sin (\Lambda - \lambda) \right) \Sigma \left(\frac{H \cos I}{\kappa\kappa''} \cdot \frac{\theta (1+\theta)}{(1+\theta f)^2} \sin h \right) \right.$$

$$\left. + \frac{q'}{\kappa''} \sin \omega \cos \lambda_1 \right] \kappa'' \delta f$$

$$+ \left(\tan I \cos (l_0 - \Omega + \Lambda) + \frac{\tan B}{\nu} \sin (\Lambda - \lambda) \right) \cdot \frac{a_0}{\kappa} \sin (A_0 + \nu_0 t)$$

$$+ \frac{b_0}{\kappa} \sin (B_0 + \mu t + \lambda_1)$$

$$\left. + \frac{\cos \lambda_1}{\cos \lambda_{11}} \cdot \frac{c_0}{\kappa} \sin (C_0 + \mu' t - \lambda_{11}) \right\},$$

$$\text{if } \tan \lambda_{11} = \frac{2}{\sqrt{f}} \tan \lambda,$$

$$+ \frac{y''}{100} \cdot \frac{100\, \delta k'}{k'}.$$

The factor κ, which is introduced on account of obvious convenience, is arbitrary, and may be put $=240$ or, perhaps better, $=300$. The most convenient value of κ'', the factor of δf, will be that of the largest of the coefficients

$$\frac{H}{\kappa} \cdot \frac{\theta (1+\theta)}{(1+f\theta)^2},$$

or that dependent on the Moon's annual equation.

I have written out the equations for $\delta x''$ and $\delta y''$ in full, retaining all the terms in symbolical form, so as to leave the question of the best numerical values which ought to be employed an open one. The substitution of numerical terms and the introduction of suitable abbreviations will, of course, greatly simplify the equations, especially in case the selected spot is near the lunar equator, a case the advantages of which are apparent at a glance.

The measures from which the observed values of $\delta x''$ and

$\delta y''$ are to be deduced furnish a series of angular distances $s_1 \ldots s_n$ of the spot from points of the Moon's limb in various position-angles $p_1 \ldots p_n$, the corresponding times being $t_1 \ldots t_n$. For these times the values of

$$\alpha', \delta', r', \mathrm{R}', \mathrm{P}, \mathrm{B}, \Lambda, x'', y''$$

(R' being the Moon's apparent semi-diameter, $\sin \mathrm{R}' = \frac{k}{r'}$), may be found by interpolation from the values of these quantities computed at intervals of, say, 20 or 30 minutes for the extent of each set of measurements. From the distances and position-angles, duly cleared from instrumental errors and from the effects of refraction, the corresponding semi-diameters $\mathrm{R}_1 \ldots \mathrm{R}_n$ are to be derived by means of the equations

$$\begin{aligned}
s_1 \sin (p_1 - \mathrm{P}_1) + x_1'' &= \mathrm{R} \sin \mathrm{Q}_1, \\
s_1 \cos (p_1 - \mathrm{P}_1) + y_1'' &= \mathrm{R}_1 \cos \mathrm{Q}_1, \\
&\ldots\ldots \\
s_n \sin (p_n - \mathrm{P}_n) + x_n'' &= \mathrm{R}_n \sin \mathrm{Q}, \\
s_n \cos (p_n - \mathrm{P}_n) + y_n'' &= \mathrm{R}_n \cos \mathrm{Q}_n,
\end{aligned}$$

in which $\mathrm{Q}_1 \ldots \mathrm{Q}_n$ are the position-angles of the observed points of the limb at the centre of the disk, reckoned from the direction of the Moon's axis.

The comparison of these $\mathrm{R}_1 \ldots \mathrm{R}_n$ derived from observation, with the interpolated values $\mathrm{R}'_1 \ldots \mathrm{R}'_n$ supplies the equations of condition

$$\mathrm{R}_1' - \mathrm{R}_1 = \sin \mathrm{Q}_1 \, \delta x'' + \cos \mathrm{Q}_1 \, \delta y'' - \frac{\mathrm{R}'}{\mathrm{R}_\circ} \delta \mathrm{R}_\circ,$$

$$\ldots\ldots$$

$$\mathrm{R}'_n - \mathrm{R}_n = \sin \mathrm{Q}_n \, \delta x'' + \cos \mathrm{Q}_n \, \delta y'' - \frac{\mathrm{R}'}{\mathrm{R}_\circ} \delta \mathrm{R}_\circ,$$

from which the corrections $\delta x''$, $\delta y''$ and $\delta \mathrm{R}_\circ$ for each set of measures are to be deduced. The correction $\delta \mathrm{R}_\circ$ is that of some conveniently chosen mean value $\mathrm{R}_\circ$, and, in case the tabular parallaxes can be depended on, is common to all the sets of measures made with the same instrument under similar circumstances.

The substitution of the corrections $\delta x''$ and $\delta y''$ derived from observation in the previously given equations leads to the equations of condition for the determination of $\delta\lambda$, $\delta\beta$, $\delta \mathrm{I}$, δf, and the others terms of the physical libration.

In order to be able to trace the influence of the irregularities of the Moon's limb, it will be well to compute the selenographical positions of the several points of the limb, which have been measured in position-angle and distance in reference

to the spot. Their selenographical longitudes λ_n and latitudes β_n are derived from the corresponding values of Q_n, Λ_n, B_n by means of the equations

$$\begin{aligned}
\cos\beta_n \sin(\lambda_n-\Lambda_n) &= -\sin Q_n,\\
\cos\beta_n \cos(\lambda_n-\Lambda_n) &= -\cos Q_n \sin B_n + \tan R_n \cos B_n,\\
\sin\beta_n &= +\cos Q_n \cos B_n + \tan R_n \sin B_n,
\end{aligned}$$

which in practice, where great accuracy is not required, may be sufficiently simplified.

Although I have left the question of the best numerical values which ought to be substituted in the formulæ an open one, some remarks which bear upon it and touch a few of the practical difficulties of the investigation will not be out of place.

An uncertainty in the determination of I is occasioned by the difficulty of disentangling δI and b_0, in case the observations do not extend over a sufficiently long period. The angle $B_0+\mu t$ is

$$\begin{aligned}
&= B_0 + m't - \frac{n'I}{i+I}t,\\
&= B_0 - (l_0-\Omega)_0 + l_0 - \Omega + \frac{n'i}{i+I}\cdot t,
\end{aligned}$$

if $(l_0-\Omega)_0$ is the value of $l_0-\Omega$ for the time $t=0$, from which t is reckoned; or, putting

$$\begin{aligned}
B_0-(l_0-\Omega)_0 &= B_1, \text{ and}\\
\frac{n'i}{i+I} &= \mu_1,\\
B_1+\mu t &= B_1 + l_0 - \Omega + \mu_1 t.
\end{aligned}$$

Hence in the equation for $\delta y''$

$$\begin{aligned}
b_0 \sin(B_0+\mu t+\lambda_1) = {}& (b_0 \sin B_1)\cos(l_0-\Omega+\lambda_1+\mu_1 t)\\
&+ (b_0 \cos B_1)\sin(l_0-\Omega+\lambda_1+\mu_1 t).
\end{aligned}$$

But the coefficient of $-\delta I$ is $\sin(l_0-\Omega+\lambda_1)$, so that the two angles differ only by $\mu_1 t$. As the period of this difference is about twenty-four years, it is obvious that observations extending only over a year or two do not allow the satisfactory determination of both unknown quantities δI and $b_0 \cos B_1$, and that one of the two must remain practically indeterminate.

A troublesome difficulty arises from the necessity of repeating a portion of the computations, in case the adopted value f is not sufficiently near the true one. Wichmann's first value $f = 0{\cdot}2603$ was derived from a preliminary solution of his longitude-equations, and it served, together with Nicollet's value of

I = 1° 28′ 47″, in the further computations. Wichmann's final deductions gave

$$I = 1^\circ\ 32'\ 9''; \quad f = \frac{789''\cdot7}{1884''} = 0\cdot419,$$

or, neglecting a_0 and b_0 on account of the uncertainty of their determination,

$$I = 1^\circ\ 32'\ 24''; \quad f = \frac{838''\cdot6}{1884''} = 0\cdot445.$$

It is to be regretted that Hartwig, instead of adopting one of these latter values, has retained in his computations the preliminary inaccurate approximations. His own final result (*Monthly Notices* for May, p. 376),

$$I = 1^\circ\ 36'\ 39''; \quad f = 0\ 507,$$

gives for ν_0 the value 1458″·5, or the period 888·6 days. Wichmann's (last) result gives 1520″·9, or period 852·1 days, while the preliminary value employed is 1728″·9, or the period 749·6 days. How far the determination of a_0 is affected by the error of the assumed value of ν_0 is at present unknown; but it need scarcely be more than hinted that the error affects most seriously the connection between the results of the observations of 1845 and of 1878. Bessel points out in Article 6 of his paper that, in case a sensible value of a_0 should be successfully ascertained, the determination of the duration of its period would afford the surest means for the exact determination of f. According to the data on page 376 the value of a_0 is found from

$$\text{Wichmann's Observations} = 183''\cdot2 \pm 80''\cdot6$$
$$\text{Hartwig's Observations} = 62\cdot3 \pm 41\cdot9.$$

It is to be hoped that before long the publication of the investigation of the Moon's libration which has been undertaken at the Oxford University Observatory will facilitate some decision of what are the best available values of I and f.

In a second paper I shall treat the problem of determining the physical libration by observations of the changes which it produces in the relative position of spots; I shall, further, show the effect of the libration upon the observations of a spot in right ascension and declination, and also consider some other questions.

Apparent Places of Comet b 1881 *from Observations made with the North Equatoreal of the Melbourne Observatory. Aperture* 4·5 *inches.* By R. L. J. Ellery, Esq., F.R.S.

Melbourne Mean Time.	Observer.	Number of Measures.	Comet−Star. R.A.	Comet−Star. N.P.D.	Comet. R.A.	Comet. N.P.D.	Star.
d h m s			m s	′ ″	h m s	° ′ ″	
May 23 6 17 17·3	W.	4	+ 2 16·72	+ 2 54·22	4 58 48·61	125 13 32·3	Lacaille 1685
24 6 22 28·9		3	− 5 39·57	+ 4 28·73			*a*
24 6 33 18·3		2	− 8 58·94	+ 7 25·11			*b*
25 18 18 56·2		2	− 4 16·12	+ 2 38·74			*c*
26 6 10 1·6		3	− 5 5·41	+ 0 35·42			*d*
26 6 17 19·5		4	−11 45·12	+ 0 33·70	5 0 16·62	123 40 44·9	B.A.C. 1644
28 18 10 56·9		3	+ 3 42·93	+ 7 4·91	5 1 35·63	122 3 49·0	B.A.C. 1564
29 5 39 5·0		6	+ 3 55·81	−14 2·46	5 1 48·51	121 42 41·4	B.A.C. 1564
31 18 22 37·5		5	+ 7 54·15	−11 5·73	5 3 12·43	119 34 13·3	Washington 2127
June 1 5 25 19·2		9	+ 0 27·56	− 1 23·01	5 3 26·26	119 6 40·0	„ 2173
3 5 27 4·4		1	−13 48·78	+ 4 25·75	5 4 36·52	116 53 37·1	„ 2251
3 5 27 4·4		1	+ 1 23·70	− 3 35·23			*e*
3 6 4 21·1		4	+ 3 16·28	+12 37·37	5 4 37·65	116 51 36·9	Washington 2163

Melbourne Mean Time.	Observer.	Number of Measures.	Comet—Star. R.A.	Comet—Star. N.P.D.	Comet. R.A.	Comet. N.P.D.	Star.
d h m s			m s	′ ″	h m s	° ′ ″	
June 4 18 15 58·8	W.	5	−11 17·45	− 2 13·56	5 5 36·14	114 51 10·3	Washington 2240 *f*
5 18 0 43·7		7	+ 1 49·10	+ 4 55·35			
6 18 17 23·6		1	− 2 4·73	− 8 39·28	5 6 56·21	111 38 44·3	Lalande 9853 *g*
8 5 36 37·1		1	− 0 12·38	+ 5 41·66			*h*
8 18 17 42·1		5	+ 0 26·64	− 4 58·90			
8 18 30 4·5		1	−19 1·39	−16 31·79	5 8 28·06	107 38 1·7	α Leporis
9 5 17 58·5		7	+ 1 11·37	+15 38·96	5 8 47·23	106 36 27·9	μ ,,
10 5 25 43·0		5	− 8 24·90	+ 4 59·94	5 9 39·29	104 7 25·2	8 ,,
10 6 3 13·6		4	+ 0 32·43	− 0 0·60			*i*
12 17 52 57·9		4	+ 0 20·66	−22 33·10	5 12 11·39	96 35 54·8	τ Orionis
12 18 30 45·3		6	− 0 33·93	+ 8 34·76			*k*

The correction for refraction has been applied where the difference of declination made it sensible.

The apparent place of Lac. 1685 has been derived from micrometric measures with B.A.C. 1511, which is in the Williamstown Catalogue. B.A.C. 1564 and 1644 were both observed in Melbourne in 1880. The approximate places of the stars which are not to be found in any Catalogue in our possession are as under:

Star.	Mag.	R.A.	N.P.D.
		h m s	° ′
a	$7\frac{1}{2}$	5 4 49	124 41
b	$7\frac{1}{2}$	5 8 9	124 37
c	7	5 4 12	123 54
d	$6\frac{1}{2}$	5 5 22	123 40
e	8	5 2 13	116 57
f	8	5 4 24	113 16
g	$8\frac{1}{2}$	5 8 9	108 32
h	9	5 8 1	107 44
i	9	5 9 8	104 4
k	9	5 12 47	96 22

The place of Lalande 9853 has been taken from the B.A. Lalande, and μ *Leporis* was observed at Melbourne with the Transit Circle on the day of the comparisons.

From the observations of the evenings of May 23, June 1 and 10, the following parabolic elements have been computed by Mr. White:

T	June 16·41135 Greenwich Mean Time.
π	265° 8′ 54″
Ω	270° 56′ 47″ Mean Equinox 1881·0.
i	63° 28′ 30″
log. q	9·865998

Motion Direct.

The errors of the middle place (C − O) are in longitude −0″·3; in latitude −5″·9.

Observations of Comet b 1881 *made at Graham's Town.*
By L. A. Eddie, F.R.A.S.

Last evening, May 27, about 7^h 10^m o'clock, I discerned a large comet about 10° or 12° above the south-western horizon on the boundaries of the constellations *Columba* and *Cœlum*, forming almost an isosceles triangle with o *Columbæ* and γ *Cœli*, about 4° north preceding o *Columbæ*. This comet appeared to the naked eye like a good-sized planetary nebula or nebulous star, with a

faint stream of light extending upwards from it towards the south-east at an angle of about 45° to the horizon, and passing midway between the two stars above-named. When viewed through an opera-glass, the nucleus appeared of a rich golden colour and of great brilliancy, having a diameter, as near as one could guess, of 1″. The glass was not sufficiently powerful to reveal any coma, but when the round ball of light forming the nucleus had set, there was still a considerable glow of golden light in that part of the tail immediately contiguous to the horizon. The tail was of a faint yellow or straw colour, about 4′ in breadth, from 6° to 8° in length, and with little if any curvature.

The comet set at 5 minutes to 8. The weather was stormy; but the sky was tolerably clear in the neighbourhood of the comet. The tail proceeded from the whole breadth of the nucleus, and not, as in the case of the Great Southern Comet of 1880, from an arc of the periphery only.

In consequence of being away from my observatory, I was unable to bring my 9½-in. Calver and 3-in. refractor to bear upon the comet.

Mrs. L. A. Eddie saw what she considered to be a comet with two tails on Thursday evening. This may probably have been the same.

Saturday, 28*th*.—Cloudy. Saw comet for a second only through a thick fog.

Sunday, 29*th*.—Cloudy. Comet not seen.

Monday, 30*th*.—Very windy and wet. A rent in the clouds about 6.15 P.M. revealed the comet, though for a few moments only. It did not seem to have moved far from where I had observed it on Thursday, about 4° north by west, but as the time afforded for observing was brief, I was unable to fix its position with any degree of accuracy. If a straight line were drawn from β to α *Columbæ* and continued to a point about 2½ times the distance of β from α, the comet was to be found on this occasion a little to the south of this point. It was still in the constellation *Columba* near the confines of *Lepus*. When viewed through the 3-inch refractor, it revealed a small but brilliant nucleus, condensed at the centre, and surrounded by an extensive coma of moderate brilliancy, even to its outer edge.

The gradation of light from nucleus to coma was sudden, though unbroken by any dark interval. The tail appeared broad, scattered and ragged, but very faint, and soon fading away to invisibility. Before, however, I could examine it carefully the clouds again concealed the comet from view, and I caught but one short momentary glance of it again during the evening, and that through a thin cloud.

Tuesday, 31*st*.—Wet and cloudy again. Saw the comet at 6·15 P.M., during an interval between the showers. It was not far from where it was seen last evening, but it had sensibly increased in brightness, and shone as a star of the second magni-

tude. The tail had also increased in length and visibility, and could be traced to about 12° or 13° from the nucleus. It extended to 2° or 3° beyond o *Columbæ*, which star it grazed with its upper edge. When viewed through the 3-in. refractor the coma seemed much broader than on the previous evening, and was fully 6′ in diameter. The width of the tail had increased to 12′ to 15′ at its widest part. The fact that this comet is increasing in brightness, tends to show, I think, that it is yet approaching us, and its slow change of apparent position with reference to the star in its vicinity would show that it is at present describing the arc of a very large orbit as it nears the Sun from the depths of space. But I fear it is yet too soon to speculate, for the very unfavourable state of our heavens which has prevailed ever since the first appearance of this comet, has quite prevented any reliable observation even with the naked eye, so that, indeed, our visitor may possibly be diminishing in brightness rather than increasing.

Wednesday, June 1*st.*—Evening beautifully clear, not a cloud in the sky. Comet visible to the naked eye at 5·30 P.M.; young moon very bright. Comet situated 5 hours 8 min. R.A. 28° S.D. approximately. The 9½-inch Calver revealed a beautiful object, somewhat resembling Pape's drawing of Donati's comet of 1858, and Brodie's of Coggia's comet of 1874. The nucleus appeared to be inclosed in a cometic envelope or series of envelopes of parabolic form. It was not, however, situated in the focus of this curve, as was the case with the comets mentioned above, but was on one side of this point, by about the breadth of its own diameter on the side towards the Sun. The immediate focus was occupied by a condensed stream of coma, issuing, as it were, from the nucleus. This stream was bounded on its exterior edge by a darker interval, also partaking of the parabolic form, but not extending over the nucleus. There was another dark rift of similar form around the cometic envelope near the interior limits of the comet; beyond this a faint light fading away to invisibility. There was also a dark interval immediately behind the nucleus, which gave it a sharp definition on its exterior edge. The tail appeared like the continuation of this luminous parabolic envelope, widening out as its distance from the focus increased, and fading away to invisibility as the luminous matter of which it is composed became more and more rare. The tail seemed to the naked eye much shorter than last evening, but this may be owing to the increased moonlight. It terminated near o *Columbæ*. The movement of this body is N.W., so that it will set earlier each evening. It set on this occasion at 7·40 P.M.

Thursday, June 2.—Sky clear till 7 P.M. when it again clouded over. Saw comet about $5^h\ 45^m$ P.M. It had moved a little to the N.W. of its position last evening, and was now about $5^h\ 10^m$ R.A. and 27° S.D. Tail could still be traced with naked eye to o *Columbæ*. When viewed through the 9½-inch Calver it was

immediately apparent that the comet had undergone a vast change since I had observed it on the previous evening, and presented quite a new character. The nucleus was still out of the focus of the parabola, but the dense stream of cometic matter which appeared to issue from it laterally on the evening before had entirely disappeared, as had also the dark interval surrounding it; but streams of light seemed now to issue in a spiral form from the exterior edge of the nucleus, and to be beaten back again towards the tail after they had reached the outer limits of the coma, and were beaten back on that side that was farthest from the nucleus. There was still a dark interval on the interior edge of the nucleus. A great portion of the detail which existed on the previous evening had disappeared, and these spiral streams issuing from the nucleus constituted the principal feature on this occasion. The nucleus appeared slightly larger but less condensed; the gradation of light from nucleus to coma was less sudden, and the coma above the nucleus somewhat brighter. The increased moonlight interfered greatly with observation.

Friday, June 3.—Cloud cleared off at sunset. Comet visible to naked eye at $6^h\ 40^m$ P.M. Tail could still be traced to *o Columbæ*, which star it grazed with its lower edge. When viewed through the $9\frac{1}{2}$-inch Calver, there was no great apparent change from last evening. The detail, however, was still more diminished by the increased moonlight; the nucleus seemed nearer to the centre of the parabola, the spiral streams emanating from the nucleus less marked, and the width of the coma narrower.

Saturday, June 4.—Evening fine. Comet visible $5^h\ 40^m$. Situated a little east of a straight line extending from *α Columbæ* to *ε Leporis*, and about as far from the latter as *α Columbæ* is from *β Columbæ*. Tail very long. When viewed with the reflector the spiral character of the jet from the nucleus could no longer be detected. Moonlight strong.

Sunday, June 5.—Early part of evening favourable. Comet visible at $6^h\ 35^m$ P.M. Tail very long (about 14°) and very straight. Through the $9\frac{1}{2}$-inch, owing to the bright background, very little visible except the nucleus and upward jet of cometary vapour slightly inclined, and bent over towards the opposite side from where the nucleus was situated.

Monday, June 6.—Cloudy.

Tuesday, June 7.—Saw comet at $5^h\ 20^m$ A.M., not long risen. Tail appeared shorter but broader than in the evening light. Too low in horizon for observation, and when it rose higher it was soon eclipsed by the approaching sunlight. Evening, cloudy.

Wednesday, June 8.—Saw comet for a few moments only at $5^h\ 45^m$ P.M. Very bright, but low in the horizon. Wet, cloudy.

Thursday, June 9.—More clouds. Comet visible for a short time about 6 P.M. Situated about 45′ north of *μ Leporis*.

Graham's Town, Cape of Good Hope,
June, 1881.

Observations of Comet b 1881 *made at Monte Video.*
By Lieut. B. E. W. Gwynne, R.A.

The diagram sent represents the approximate position of a comet with reference to the surrounding stars, seen from H.M.S. *Garnet* whilst laying at Sandy Point Road (Straits of Magellan) on the night of May 30, 1881, at 6.30 P.M. Ship Mean Time. I only had time to take two good sextant angles with *Sirius* and *Canopus*, which were: corrected 26° 18′ (*Canopus*), 26° 10′ (*Sirius*); approximate R.A. of comet $5^h\ 2^m$; Decl. of Comet 26° 40′ S. The later observations were as follows:—

Date 1881.	Sirius.	L.M.T.	Canopus.	L.M.T.	Achernar.	L.M.T.	Remarks.
May 31 Bar. 29·80 Ther. 33	25 38 30	6 5	27 14 10	6 10	45 39 10	6 15	Latitude and Longitude of Observer
June 1 Bar. 29·94 Ther. 36	25 9 10	5 56	28 7 0	6 0	46 30 50	6 3	53 10 20 S.
June 2 Bar. 30·10 Ther. 40	24 34 0	5 45	29 2 50	5 49	47 30 30	5 52	70 53 17 W.

The above are carefully observed sextant angles (corrected for index error) between the comet's nucleus and the stars *Sirius*, *Canopus*, and *Achernar*.

The following will give a good idea of the position of the comet on the evening of June 1, at 6 P.M. Ship Mean Time.

A line drawn from *Sirius* at right angles to a line joining *Canopus* and *Rigel*, and produced 4° beyond it, passed through the nucleus of the comet.

The axis of the comet's tail was parallel to the line joining *Canopus* and *Rigel*.

The nucleus presented the appearance of a planet (such as *Jupiter*) with its brilliancy "dulled" by the nebulous matter that slightly precedes as well as surrounds it and also forms its tail. The latter subtended an arc of about 4°, and pointed towards *Canopus*, whilst the nucleus points to *Rigel*.

Observations of Comet b 1881 *made at Pretoria.*
By E. C. Markwick, Esq.

I send a short account of a comet which has been lately visible in the Southern Hemisphere, and which has been to an astronomical eye a beautiful object.

On the evening of May 30, about 6.30 P.M. local time, my attention was attracted by a nebulous-looking star in the S.W. quarter of the sky, and not 20° above the horizon. In a few moments I could detect a faint tail, and on looking at it through a small achromatic of $1\frac{3}{4}$ inches aperture, saw at once that it

was a very pretty comet, with a brilliant head. No distinct nucleus could then be seen, but the central brilliancy was gradually softened off all round with a woolly light. The tail seemed to start back in a straight line opposite to the Sun's direction, and faded away rapidly, although with the naked eye I should estimate it might be traced some 4° or 5°, if not more. It was inclined to the horizon at an angle of between 30° and 40°. The head was situated at the apex of a right-angled triangle constructed on the line joining β *Columbæ* and α *Leporis*, and, as far as I could judge roughly (on comparison with Proctor's smaller star atlas) was in R.A. 5^h 0^m, S.D. 32°.

On May 31, at 6·30 P.M. the general appearance was unchanged; perhaps it was a shade brighter. Position roughly estimated, R.A. 5^h 0^m, S.D. 30°. Head about equal distances from *Sirius* and *Canopus*. In intrinsic brightness I estimated it between β and γ Leporis, or between 4th and 5th mag., but owing to there being quite a disk visible to the naked eye, the head appeared more like a 2nd mag. star. With the telescope there was a distinct nucleus visible in the head, although rather dull. The upper edge of the tail passed just over *o Columbæ*, and I could not fairly trace it beyond, although faint glimpses of a further extension could occasionally be caught by averted vision.

June 1.—Comet perceptibly increased in brilliancy. At 6.10 P.M. I took alignments, and found the head as near as might be in a line with β and α *Columbæ*, and two-thirds the distance between β and α *Leporis*, below a line drawn through those stars towards *Columba*. Hence I estimate its position at R.A. 5^h 0^m, S.D. 28° 30′. The direction of the tail was from this point towards ζ *Pictoris*, the direction having apparently changed since last night. Nucleus woolly, and not well-defined. To the naked eye it looked like a beautiful, dull rocket. A faint star could be seen through its tail, and several near.

June 2.—Cloudy; no satisfactory observations.

June 3.—First seen at 6 P.M. Undoubtedly brighter; but it is getting low in the west, and the increasing moonlight interferes much with its appearance. Taking angles with a pocket sextant (without corrections for refraction), I found the head to be—

At 7 P.M., 24° 0′ from *Sirius*,
and 29° 55′ from *Canopus*.

Taking eye observations, I noted it as three-fourths the distance between α and β *Leporis*, below a line joining those stars and produced; and two-thirds the distance between α and β *Columbæ* to the right or N. of a line joining those stars and produced.

June 4.—Comet very badly situated for observation. Angles with sextant:—

At 6^h 35^m P.M., 23° 43′ from *Sirius*.
At 6^h 40^m P.M., 30° 53′ from *Canopus*.

June 5.—Comet well seen, considering its bad position for observation. At $6^h\ 5^m$ P.M. noted the nucleus as star-like in the telescope, but later on this was not so apparent. I have some idea a star might have been in close contiguity to the nucleus. Angles :—

At $6^h\ 20^m$ P.M. 23° 4′ from *Sirius*.
32° 16′ „ *Canopus*.

June 6.—Nucleus seen. Brightness of the comet has, I fancy, increased, but it is much obscured by moonlight. Tail could be traced for some 5° or more.

At $6^h\ 15^m$ P.M., 22° 31′ from *Sirius*.
33° 49′ „ *Canopus*.
17° 6′ „ *β Canis*.

June 7.—Comet getting much brighter, although obscured greatly by moonlight. Position :—

At $6^h\ 10^m$ P.M., 22° 10′ from *Sirius*.
At $6^h\ 19^m$ P.M., 35° 28′ „ *Canopus*.

June 8.—Approaching the Sun rapidly. Position :—

At $6^h\ 17^m$ P.M. 21° 53′ from *Sirius*.
37° 25′ „ *Canopus*.

Since the last date I have not seen it, and conclude it has disappeared below the horizon.

I forward two sketches, one showing the general appearance of the comet to the naked eye, the other as seen in a small achromatic of about two inches aperture. There was no marked change in the general features during the whole period of its visibility. These sketches, however, represent it, I think, pretty fairly for June 1 at 6.30 P.M.

Pretoria, Transvaal,
South Africa :
1881, *June* 16.

Elements of Comet b 1881. By A. Graham, Esq.

The calculations were founded on the following meridian observations :

	G.M.T.			
	h m s	h m s	° ′ ″	
1881, June 23	11 30 54·4	$\delta\alpha = 5\ 34\ 55{\cdot}2$	$\delta\Delta = 44\ 53'\ 20''{\cdot}6$	Oxford
29	11 37 39·3	6 5 20·5	24 11 37·9	Oxford
July 4	11 58 36·3	6 51 29·1	14 47 0·9	Cambridge

After correcting for Aberration and Parallax from the elements by Dr. H. Oppenheim, given in the *Dun Echt Circular*, No. 24, a careful calculation gave:

T = 1881, June 16·45914 Greenwich Mean Time.

$\pi = 265^\circ\ 14'\ 46''.4$ Mean Equinox 1881·0
$\Omega = 270\ 58\ 1''.2$ „
$i = 63\ 28\ 20''.0$
log. $q = 9.865812$

Heliocentric motion, direct.

The calculated middle place compared with the observed, gives:

C − O in longitude $+2''.6$ in latitude $+2''.8$

The heliocentric equatoreal coordinates, referred to the apparent equinox, June 30·0, are:

$x = [9.650203] \sin(356^\circ\ 28'\ 10''.6 + v)$ $d \log a = +.144 d\Omega$, $dA = +2.237 d\Omega$
$y = [9.991862] \sin(243\ 26\ 31''.4 + v)$ $d \log b = -.344 d\Omega$, $dB = +0.384 d\Omega$
$z = [9.961381] \sin(328\ 29\ 46''.3 + v)$ $d \log c = +.362 d\Omega$, $dC = +0.091 d\Omega$

The corrections to the logarithms are to be applied to the units in the sixth decimal place, $d\Omega$ is expressed in seconds of arc, and v represents the true anomaly.

On 1881, July 13, with the Northumberland Equatoreal and square bar micrometer, five careful comparisons were made with B.A.C. 3199, which is contained in the Greenwich Observatory Catalogue of 2263 Stars, No. 908. Using the Greenwich place, the results, corrected for Parallax and Aberration, are:

1881, July 13·451648 G.M.T. $\alpha = 9^h\ 18^m\ 33^s.83$, $\delta = 81^\circ\ 49'\ 18''.5$

An Ephemeris calculated from my elements gives:

$\alpha = 9^h\ 18^m\ 33^s.79$, $\delta = 81^\circ\ 49'\ 20''.9$

There is thus hardly any room for doubt that the orbit is very nearly a parabola.

The Observatory, Cambridge:
1881, *September* 9.

Observations and Elements of Comet b 1881.

By J. Tebbutt, Esq.

By a previous mail I sent to Europe my report of the appearance of a comet, and I have now the honour to supplement it by my observations and an approximate determination of the orbit. The following positions, with the exception of that for June 11, were obtained with the filar micrometer of the $4\frac{1}{2}$-inch Equatoreal, the differential measures being all corrected for refraction. The corrections for parallax may be obtained by means of the log. factors $\frac{p}{P}$, $\frac{q}{P}$, p and q denoting the corrections in time and arc respectively, and P the comet's equatoreal horizontal parallax in arc. When the comet was first detected no tail could be distinguished without optical aid. Traces of a tail were, however, seen without a telescope on the following evening, and on the 25th it was about two degrees in length. Measures on the evening of June 1 gave $8\frac{1}{2}$ degrees as the length of the appendage, but increasing moonlight prevented its being seen to advantage. The nucleus was brilliant and well defined in the telescope. The comparisons with Lacaille 1685 were not good, owing to the proximity of the objects to the horizon. Those of June 4 were also unsatisfactory, and on the morning of the 12th the comet was only compared in the twilight with *Rigel* by means of the circles of the Equatoreal.

Windsor Mean Time 1881.	App. R.A. of Comet	Log. Factor for Parallax $\frac{p}{P}$	App. N.P.D. of Comet	Log. Factor for Parallax $\frac{q}{P}$	No. of Cp.	No. of Cp. St.
	h m s		° ′ ″			
May 22, 6 56 24	4 58 20·90	+8·8351	125 39 54·9	+9·6475	8	1
23, 7 1 17	4 58 52·38	+8·8326	125 13 45 0	+9 6666	7	2
23, 7 35 26			125 13 2·8	+9·7287	3	3
23, 7 39 19	4 58 52·60	+8·8243			2	3
25, 7 3 37	4 59 48·23	+8·8264	124 13 16·7	+9·6886	7	4
27, 18 9 44	5 1 3·46	−8·8166	122 45 53·7	+9·7163	1	5
June 1, 6 22 4	5 3 27·15	+8·8034	119 5 16·5	+9·6795	12	6
2, 6 42 37	5 4 2·86	+8·7970	118 0 55·7	+9·7195	1	7
4, 6 46 24	5 5 13·65	+8·7851	115 32 55·9	+9·7387	3	8
5, 6 25 42	5 5 53·74	+8·7835	114 7 40·5	+9·7216	5	9
6, 6 14 30	5 6 33·29	+8·7792	112 32 31·3	+9·7149	5	10
6, 6 14 30	5 6 33·22	+8·7792			5	11
8, 6 12 59	5 8 0·91	+8·7680	108 46 24·4	+9·7288	5	12
11, 18 27 36	5 11 8·08	−8·7454	99 47 52·1	+9·7154	3	13

Adopted Mean Places of the Comparison Stars for 1881·0, *and Apparent Places for the Dates of Observation.*

Comp. Star.	R.A. Mean. h m s	R.A. App. s	N.P.D. Mean. ° ′ ″	N.P.D. App.	Authority for Star's Mean Place.
1	5 0 7·62	7·50	125 38 49·1	52·9	*Wash. Gen. Cat.* 1860 + *Wash. Obs.* 1875 + *Cape Cat.* 1860 / 3
2	5 2 8·52	8·42	125 11 42·9	46·6	*Lacaille's Cat.* 1750, No. 1722
3	4 56 34·32	34·22	125 11 5·9	9·0	„ „ No. 1685
4	4 55 40·27	40·20	124 20 16·6	19·0	„ „ No. 1681
5	5 11 58·40	58·42	122 38 39·0	42·5	„ „ No. 1785
6	5 2 58·53	58·70	119 8 1·0	2·3	*Wash. Gen. Cat.* 1860, No. 2173
7	5 32 34·62	34·86	117 56 28 9	33·1	„ „ No. 2342
8	5 11 43·63	43·95	115 27 51·0	52·5	„ „ No. 2217
9	5 8 9·50	9·87	114 6 21·0	21·9	*Wash. Mural Cir. Zones*, 156, 1848, No. 11
10	5 0 25·36	25·80	112 31 56·0	55·7	*Nautical Almanac*, 1881
11	5 4 42·20	42·63			*Ann. de l'Obs. Roy. de Bruxelles Cat.* 1874, No. 116
12	5 8 12·07	12·63	108 41 50·4	50·7	*Oeltzen Argelander, Sud.* No. 3773
13	5 8 49·11	49·97	98 20 26·1	25·9	*Nautical Almanac*, 1881

In bringing up the places of the stars the proper motion has been taken, where possible, from the B.A. Catalogue. It will be necessary to re-determine the places of Lacaille's stars in the meridian at the close of the year.

From the comet's positions for May 22, June 1 and 11, uncorrected for Aberration and Parallax, I have deduced the following parabola :—

Perihelion passage, 1881, June 16·30995, Greenwich Mean Time.

Longitude of the perihelion ...	264° 56′ 16″ M. Eq. 1881·0
Longitude of the ascending node ...	270° 54′ 0″ „
Inclination of the orbit	63° 27′ 14″
Perihelion distance	0·7357075
Motion	Direct.

These elements resemble those of the Great Comet of 1807, and were it not that Bessel assigned the long period of 1714 years to that comet, I should regard the late visitor as identical with it. At the time of the comet's nodal passage the Earth was at no great distance from the prolongation of the axis of the comet's tail, and it will be seen that the comet's orbit approached very near to that of the planet *Venus*.

Observatory, Windsor, N. S. Wales :
1881, *August* 10.

Fall of a Meteorite on March 14, 1881. By Prof. A. S. Herschel, M.A., F.R.A.S.

A stonefall took place at 3.35 p.m. on the above date a mile and three quarters from Middlesborough, in Yorkshire, along the branch line of the North Eastern Railway from Middlesborough to Guisborough, at a place known as Pennyman's Siding on the railway. The fall was accompanied by the usual thunder-like report, not heard at the place where the meteorite struck the earth, but as far off as Northallerton and Welbury in Yorkshire.

Some workmen's attention on the railway was drawn for about four seconds to a whirring noise overhead, followed immediately by a heavy thud in the ground near them; and on searching in the direction indicated by the sound, they found the stone, about three minutes afterwards, at the bottom of a hole eleven or twelve inches deep which had formed almost vertically through an inch of coke ballast and through thin growing turf and stony clay below at the foot of the slight embankment of the railway, four yards from the nearest line of rails, nineteen yards from the signal-box of the siding, and forty-eight yards from the place where they stood when they heard the sound. The foreman narrated the occurrence, and placed the stone in the hands of the engineer of the Darlington district of the railway, Mr. Cudworth, in whose possession it now remains as property of the railway company; but it was submitted to me on March 25 for examination, and on Saturday, March 26, I visited the place of fall with Messrs. Cudworth and Ellinor and the workmen under them, and with some scientific friends. A photograph of the site, and of the group of men finding the stone, has since been made, and steps are being taken for preserving the hole in the ground in a box fitted and screwed together round the earth about it, which will be thus bodily removed.

The stone weighs 3 lbs. 8 oz. 83 grains, and is of a low pyramidal shape like an upper oyster-shell, three inches thick and rather less than 6 in. × 5 in. in length and breadth. The interior is visible at points of the frayed edge and is grey, with very little interspersed grains of iron pyrites, and apparently no iron; and a magnet is not sensibly affected by the mass. Its specific gravity roughly determined is a little greater than 3·0. The flat back surface of the meteorite is covered with a rough brown crust, while the blunt conical front surface is deeply scored and furrowed radially from the centre, and polished like fresh molten slag and of a lead-grey colour.

The singular form and contour of the stone make it very desirable that, whatever provision is finally made for its preservation and mineralogical examination and description, it should not undergo more defacement from its original integrity than is absolutely necessary.

On a simple Approximate Method of calculating the Effect of Refraction upon the Distance and Position-angle of Two Adjacent Stars. By Robert S. Ball, Esq., Royal Astronomer of Ireland.

In connection with the Parallax Observations on which we are engaged at Dunsink I have found it convenient for some purposes to construct the four small tables here given. These tables show by inspection the corrections in tenths of a second of arc to the distance, D, and in whole minutes to the position-angle, p.

The distances in our measurements are generally under 300″. The tables only refer to zenith distances between 45° and 70°. Between 45° and the zenith the correction to the position-angle is presumed to be negligible and the correction to the distance may be taken at + 0″·1 per 300″. Below 70° of zenith distance more accurate calculations would be required than the tables can give.

TABLE I.

Refractions, Distance, and Position.

North Declination.

10°	20°	30°	40°	50°	60°	70°	80°	
1·0	2 6	3·6	4·3	5·1	5 9	7 0	10	
13	33	43	49	55	58	56	25	45°
2·0	3 2	4·1	4·9	5·8	6·6	8·2		
23	35	43	48	51	50	40		50
2 8	3·9	4·7	5·6	6·4	7·5	9·7		
29	38	43	47	47	43	25		55
3·5	4·5	5·3	6·1	7·2	8·7			
33	39	43	44	41	33			60
3·9	4·7	5·6	6·5	7·7	9·5			
36	39	42	42	38	24			63
4·2	5·1	6·0	7·0	8·2	11·0			
36	40	42	40	34	10			66
4·4	5·4	6·2	7·3	8·6				
36	40	40	37	30				68
4·6	5·6	6·5	7·6	9·0				
35	39	39	35	27				70

TABLE II.

Position-Angle – Parallactic Angle.

Zenith Distance.	360 / 180 / 180 / 0	350 / 190 / 170 / 10	340 / 200 / 160 / 20	330 / 210 / 150 / 30	320 / 220 / 140 / 40	310 / 230 / 130 / 50	300 / 240 / 120 / 60	290 / 250 / 110 / 70	280 / 260 / 100 / 80	270 / 270 / 90 / 90
45°	2		2	1	1	1	1	1	1	1
50	2	2	2	2	2	1	1	1	1	1
55	3	2	2	2	2	2	1	1	1	1
60	3	3	3	3	2	2	1	1	1	1
63	4	4	4	3	3	2	2	1	1	1
66	5	5	5	4	3	3	2	1	1	1
68	6	6	5	5	4	3	2	1	1	1
70	7	7	6	5	4	3	2	2	1	1

TABLE III.

Position-Angle.

Parallactic Angle.	0 / 180	20 / 200	40 / 220	60 / 240	80 / 260	100 / 280	120 / 300	140 / 320	160 / 340	180 / 36
−50	− V	−IV	− II	− I	o	o	−II	−III	− V	− V
−30	−IV	− V	−IV	−II	−I	o	o	− I	−III	−IV
−10	− II	−III	−III	−II	−I	+I	+II	+ I	o	− II
+10	+ II	o	− I	−II	−I	+I	+II	+III	+III	+ II
+30	+IV	+III	+ I	o	o	+I	+II	+IV	+ V	+IV
+50	+ V	+ V	+III	+ I	o	o	+ I	+ II	+IV	+ V

TABLE IV.

Zenith Distance.	o	I	II	III	IV	V
45°	0	0	0	1	1	1
50	0	0	1	1	1	1
55	0	0	1	1	2	2
60	0	1	1	2	2	3
63	0	1	1	2	3	4
66	0	1	2	3	4	5
68	0	1	2	4	5	6
70	0	1	3	5	6	7

Table I. is for the purpose of finding an approximate value of the zenith distance, Z, and the parallactic angle, η.

Rule.—Enter I. with declination and hour angle in decimals of an hour; then Z is found along the horizontal line and η is found under the hour angle.

Example—Declension 50° and hour angle $8^{h}\cdot2$; then Z is 66° and η is 34°.

N.B.—η is to be taken + when the object is to the West of the meridian, and − on the East.

Table II. gives refraction for tenths of a second for a distance of 300″.

Rule.—Enter II. with Z and $p-\eta$, and obtain the additive correction in tenths of a second for a distance of 300″.

Example.—$Z=66°$; $\eta=-34°$; $p=296°$; then correction for refraction for a distance of 300″ is $+0''\cdot4$, and for any distance D″ is $+0''\cdot4\times D\div300$.

Tables III. and IV. give refraction in minutes of position-angle.

Rule.—Enter III. with η and p, and then IV. gives correction in minutes taking sign from III.

Example.—$Z=66°$; $\eta=30°$; $p=140°$; correction for refraction $=+4'$: or $Z=63°$; $\eta=30°$; $p=340°$; correction for refraction $=-2'$.

Errata.

Page 190, line 16, *for* xxxiii. *read* xxiii.
„ 196, „ 26, „ 1881 „ 1880.

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